Paleoseismology of the Saddle Mountain West Fault, Eastern Olympic Peninsula, Mason County, Washington:
Collaborative Research with William Lettis & Associates, Inc. and the U.S. Geological Survey

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Investigations Undertaken

This research investigates the Holocene earthquake history of the Saddle Mountain West fault, one of several active reverse faults that border the southeastern margin of the Olympic Mountains near Hood Canal, Mason County, Washington (Figure 1). Trenching investigations in the early 1970s reported evidence for latest Pleistocene and latest Holocene displacements on northeast-striking, east-side-up reverse faults within the Saddle Mountain fault zone, including the Saddle Mountain West, Saddle Mountain East, and Dow Mountain faults (Carson, 1973; Wilson et al., 1979). Recent lidar imagery reveals earthquake-related topographic scarps that show the fault zone is more extensive than previously realized (Figure 2). Radiocarbon dates from a buried forest soil and tree-ring analyses of drowned, in-place stumps indicate that both the West and East strands of the fault zone ruptured simultaneously or nearly simultaneously and raised the level of Price Lake about 1,000 to 1,300 years ago (Wilson et al., 1979; Hughes, 2005). Magnetic surveys across the West fault, using a canoe, identify a 150-m wide, northeast-trending anomaly beneath the western end of Price Lake (Blakely et al., 2005). Two east-side-up reverse faults with 20-m displacements at depth that align with surface scarps illuminated by lidar surveys (Haugerud, 2003) provide model fits that best explain the anomaly (Blakely et al., 2005).

Our investigation of the Saddle Mountain West fault involves five main tasks. First, we compiled existing geologic information and interpreted historical aerial photography and lidar imagery (Figure 3). Second, we documented a 17-m long trench across the West fault south of Price Lake using standard paleoseismic trenching methods for investigations of reverse and oblique strike-slip faults (e.g., McCalpin, 1998). Third, we examined sediment cores along an 80-m long transect across the fault scarp where it projects beneath wetland sediments adjacent to the south-western edge of Price Lake. Fourth, an earthquake chronology will be developed using the results of radiocarbon analyses of charcoal and detrital organic litter sampled from the trench and sediment cores. Finally, we are in the process of analyzing data collected in the field and preparing the Final Technical Report as stipulated in the NEHRP award contractual agreement.

We acknowledge preliminary information and data from related USGS field studies of Price Lake shared by J. Hughes and R. Blakely. Professor R. Carson and his industrious students M. Zeliff and C. Iacoboni of Whitman College provided considerable assistance

with the interpretation and description of geologic units, logistical tasks in the trench and completed the stratigraphic transect across the scarp. H. Kelsey interpreted soil stratigraphy in the trench and Ray Witter assisted with trenching and the stratigraphic transect.

Results

The surface expression of the Saddle Mountain West fault reflected in lidar imagery includes a 3- to 4-km long, northeast-trending series of scarps that extends from the northwestern flank of Dow Mountain on the south, across the Price Lake basin and Saddle Mountain, to Lilliwaup Swamp on the north (Figure 2). Near Cargill Creek, north of Dow Mountain, a single, 1- to 2-m high scarp deforms Vashon glacial till and outwash deposits and post-glacial alluvial deposits (Figure 3). The scarp is concealed beneath Price Lake and surrounding latest Holocene alluvial, wetland and lacustrine deposits. However, 1997 aerial photography and field reconnaissance reveal an increase in lake bathymetry to the west of where the scarp projects into the water suggesting that the scarp deforms the lake floor. Northeast of Price Lake multiple topographic lineaments, including both east- and west-facing scarps, climb the southern flank of Saddle Mountain toward the graben-like cleft in the ridge that defines its name (Figure 3). A west-facing scarp coincides with the eastern edge of the “saddle” and an east-facing scarp coincides with the western saddle edge. North of Saddle Mountain, the scarps project toward the eastern linear termination of Lilliwaup Swamp that is impounded to the east by topographically higher Vashon glacial till (Figure 3).

A 17-m long trench excavated across the Saddle Mountain West fault scarp south of Price Lake exposed faulted Vashon glacial till and overlying post-glacial colluvial deposits. Northeast-striking primary faults and fractures dipping 55° to 80° southeast and secondary fractures with similar strikes but dipping 50° to 55° north characterized the 10-m wide deformation zone. Total vertical separation of the contact between glacial till and overlying colluvium across the entire fault zone is about 1.4 to 1.5 m. Total vertical separation of the land surface across the scarp is approximately the same amount. We interpret at least two earthquakes from structural and stratigraphic relations in the trench exposure. Pending results of radiocarbon analyses of detrital charcoal fragments from colluvial deposits will provide age constraints for the time of faulting.

Possible evidence for a right-lateral lateral component of slip comes from an offset basalt cobble observed in the west wall of the trench. Both fragments of the faulted cobble were firmly cemented in glacial till and showed on evidence of rotation. The intersection of a linear groove on the cobble surface with the fault plane striking N 47° E and dipping 58° S provided a piercing point to estimate a slip vector. Direct measurement of the piercing point yield a displacement estimate of 7.5 cm along a slip line with a rake of 51° to 56° NE. These data indicate right-lateral oblique reverse displacement of the cobble with a 1.5:1 horizontal to vertical slip ratio.

A stratigraphic transect across the West fault, obtained using a hand auger, provides preliminary constraints on apparent vertical separation of the contact between probable post-glacial outwash deposits and overlying late Holocene wetland and lacustrine deposits. The 80-m long core transect was positioned perpendicular to a subdued step in topography aligned with the projected trace of the Saddle Mountain West fault scarp. Ten sediment cores were used to develop a subsurface profile that reveals interbedded forest soil, peat and soft silt to sandy silt overlying impenetrable gravel. The contact between gravel and overlying silty and organic-rich sediments shows a vertical separation of 1.25 m across the subdued topographic scarp. The lower elevation of the contact and increasing thickness of overlying sediments to the northwest of the scarp is consistent with east-side-up deformation observed across faults in trench exposures.

The results of this investigation will provide better estimates of earthquake recurrence intervals, Holocene slip rates, and assess the styles of coseismic surface deformation across the Saddle Mountain fault zone. New insights on the rates and styles of deformation in the eastern Olympic Peninsula will help improve regional strain models for western Washington. Current strain models infer northward migration of the Cascadia fore arc but do not explain upper-plate faults in the eastern Olympic Peninsula (e.g. Wells et al., 1998). Focal mechanisms of microseismicity inverted for strain indicate that northwest-southeast shortening and crustal thickening is occurring along the eastern Olympic Peninsula (Lewis et al., 2003). These data and other geological observations on the Olympic Peninsula are inconsistent with north-south shortening motivating the need for further study.

Finally, we have coordinated our efforts with ongoing paleoecological studies of sediments beneath Price Lake and the surrounding bog that record Holocene earthquakes, conducted by Dr. Jonathan Hughes, a USGS Mendenhall Fellow. Together, the integrated results of both projects will contribute to a better characterization of the seismic potential of the Saddle Mountain fault zone in western Washington.

Non-technical Summary

This research studies the recent earthquake history of the Saddle Mountain West fault, one of several active reverse faults in the southeastern Olympic Peninsula, Mason County, Washington. The investigation involves interpretation of fault scarps on lidar imagery, documentation of a 17-m long trench and a sediment core transect across the West fault, radiocarbon dating to estimate earthquake timing, data analysis and reporting. Preliminary results indicate a total of 1.25 to 1.5 m of east-side-up vertical deformation across the West fault in post-glacial deposits. Part of the fault movement may have involved right-lateral displacement. The results of this study will be used to improve seismic hazard maps for western Washington.

Reports Published

None to date.

Availability of Geologic Data

A photomosaic of the trench exposure and preliminary interpretive trench log in PDF format is available. Please contact R. Witter (witter@lettis.com) or R. Givler (givler@lettis.com) at 925-256-6070 to request these data.

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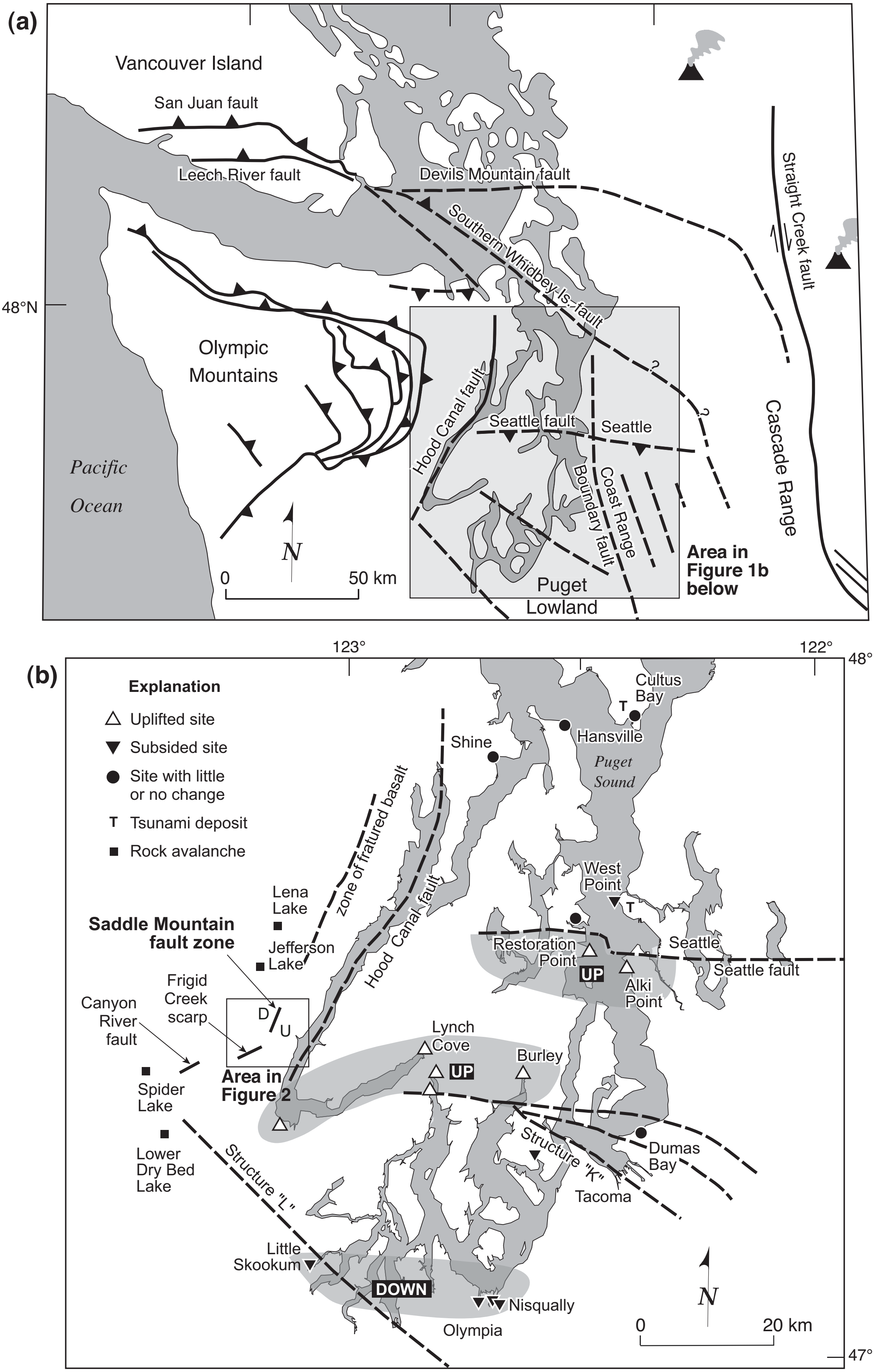

Figure 1. (a) Tectonic map of western Washington modified from Johnson et al. (1999) showing crustal faults in the Puget Lowland bound by the Olympic and Cascade Mountain ranges. (b) Map showing regions of tectonic uplift and subsidence, tsunami deposits, and rock avalanches in the Puget Lowland that occurred about 1,100 years ago (modified from Sherrod, 2001; Bucknam et al., 1992; Atwater and Moore, 1992). Fault locations from Johnson et al. (1999), Gower et al. (1985), and unpublished data of Sherrod (pers. comm. 2003).

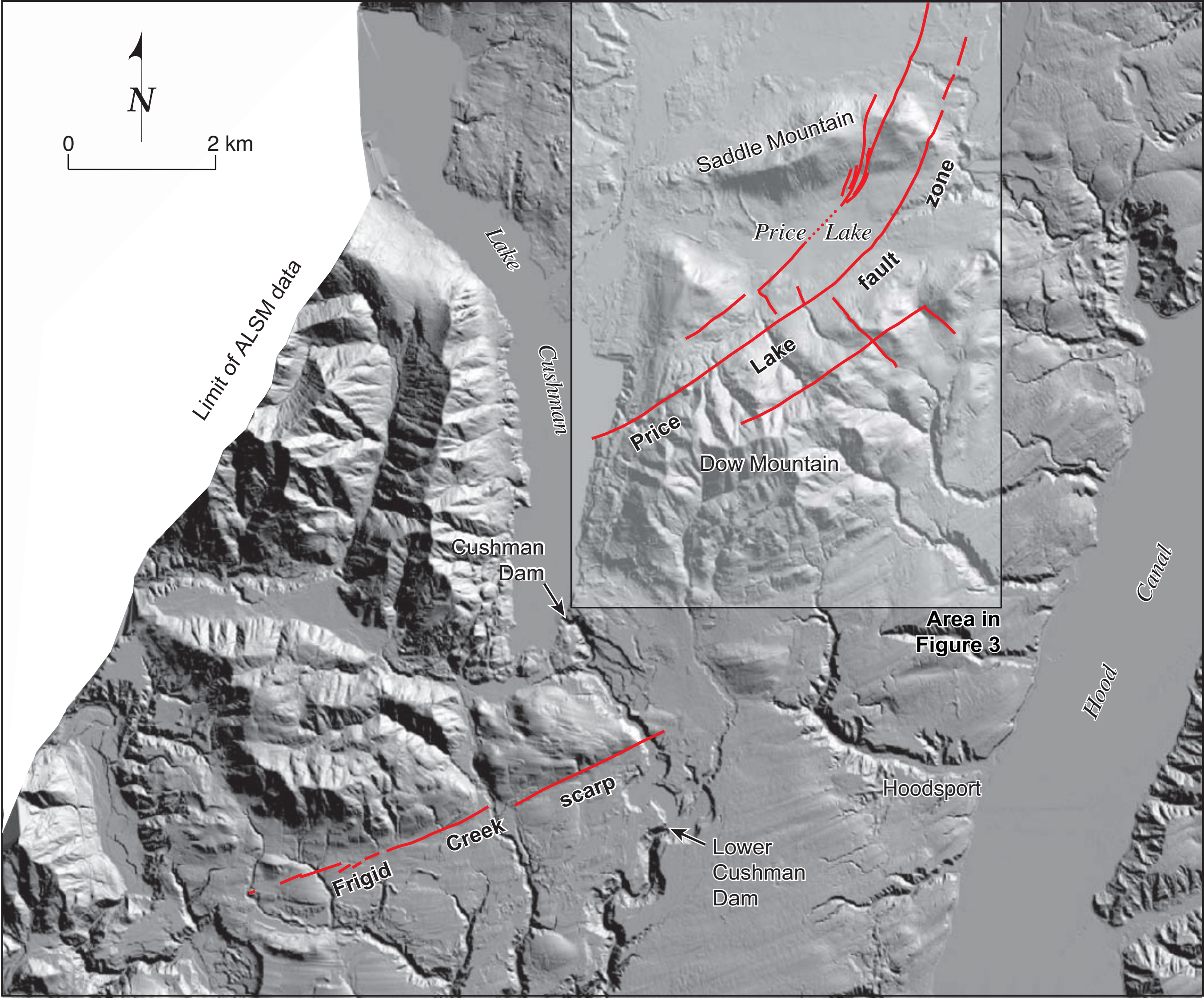

Figure 2. Light detection and ranging (lidar) image of the southeastern Olympic Peninsula near Hoodsport, Mason County, Washington showing northwest-facing scarps of the Price Lake fault zone and recently identified southeast-facing scarps near Frigid Creek. The Saddle Mountain fault zone consists of two to three northeast-striking reverse faults that traverse across the northern flank of Dow Mountain, through Price Lake to the northeast and bisect Saddle Mountain. Several northwest-trending topographic scarps and lineaments intersect the northeast-striking faults suggesting that the fault zone may consist of a series of imbricated reverse faults and perpendicular tear faults. Previous study of the Saddle Mountain faults by Wilson et al. (1979) reported evidence for latest-Pleistocene and Holocene displacement. For a detailed lidar image and corresponding geologic map of the Price Lake fault zone see Figure 3.

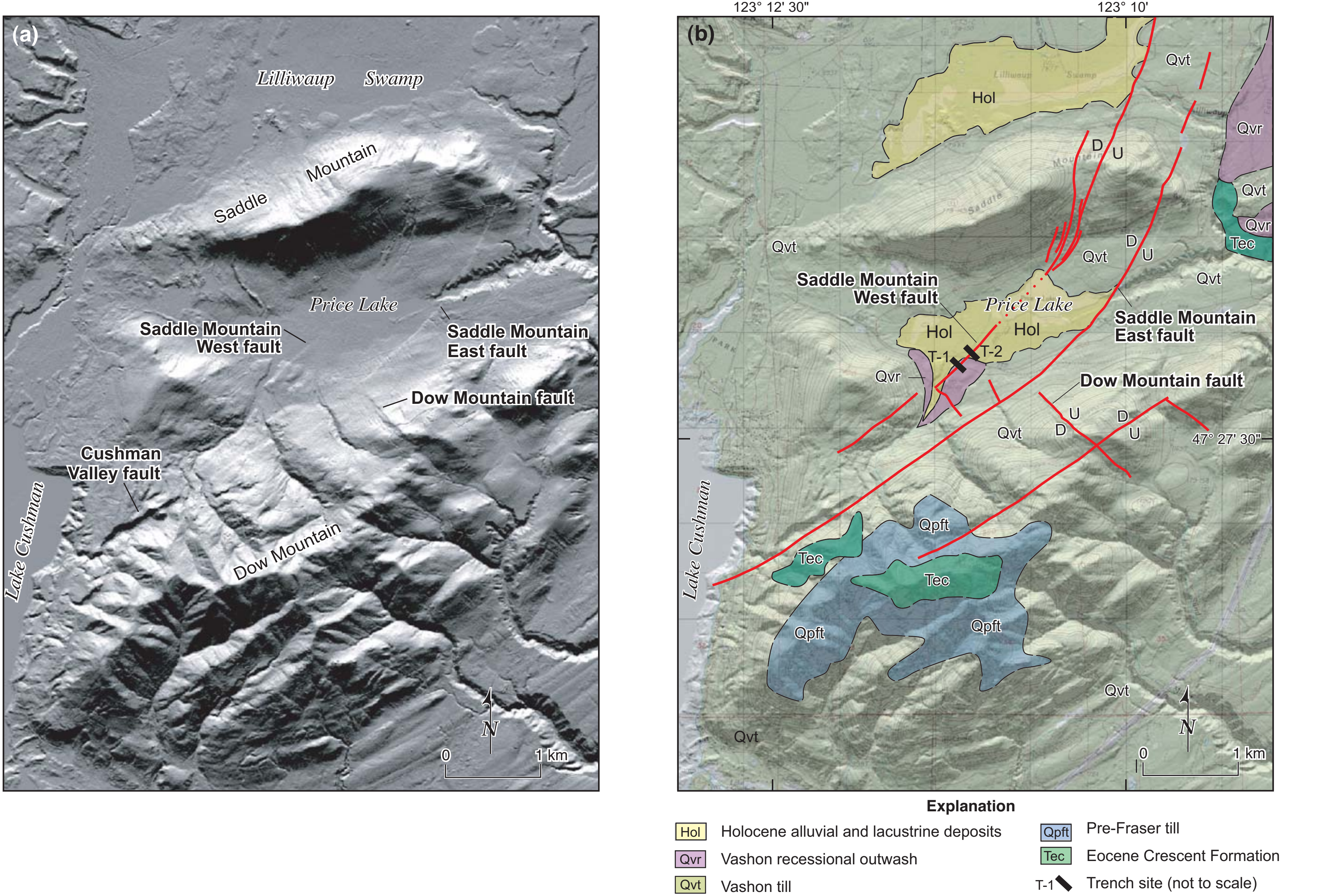

Figure 3. (a) Lidar image of the Price Lake area showing topographic scarps that delineate the Saddle Mountain West, Saddle Mountain East, and Dow Mountain faults previously studied by Wilson et al. (1979). Interpretation of the lidar data has identified additional northeast- and northwest-trending scarps that appear to reflect a coherent system of southeast-dipping reverse faults cut by northwest-striking tear faults. (b) Topographic map of the Price Lake area showing fault scarps interpreted from lidar image at left and Quaternary geology modified from Wilson et al. (1979). The trench sites across the Saddle Mountain West fault are discussed in detail in the text.

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